Tongue Thrust: Another Look At The Evidence Part I

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The subject of tongue thrust is a very controversial one. Most of the literature on the subject takes the form of reports of clinical experience or expressions of opinions. The majority of research on this topic has involved investigations in which a limited number of subjects were studied and inadequate control procedures were utilized.

Some well-controlled research evaluating orofacial muscle pressures exerted on the teeth has been published by William Proffit. The May, 1974 issue of the Journal of Speech and Hearing Disorders contained an interesting article on the tongue thrust controversy (Mason and Proffit). In this paper, the authors presented their views on several controversial issues, as well as a review of pertinent research and opinions to support those views. At least 30 significant statements were made regarding tongue thrust, its relationship to malocclusion, and its treatment.

The American Speech and Hearing Association has, for some time, been making an effort to determine the relevance of tongue thrust to speech pathology, The general thrust of the Mason Proffit article was that myofunctional treatment of tongue thrust has been administered too often and too early. Moreover, they suggest that traditional therapy for an elementary school child exhibiting a frontal lisp, accompanied or not accompanied by a tongue thrust, is the treatment of choice for such children. Only if tongue thrust persists into adolescence do Proffit and Mason advocate oral myotherapy.

A personal appraisal of the Mason-Proffit article indicated sixteen statements or issues with which the present author agreed, and fourteen issues with which he disagreed. The purpose of this article is to summarize these areas of agreement and disagreement and to offer an alternative set of conclusions and inferences based on his own interpretation of present knowledge of the field that is becoming known as "oral myology."

The Mason-Proffit article will be used as a basis upon which to offer these opposing conclusions and inferences. The literature referred to by those authors will be examined, as well as other pertinent research articles, including the present author's. A basic assumption of this report is that there are important advantages to treating tongue thrust prior to adolescence.

Areas of agreement. In order of their mention in the Mason-Proffit article are the following conclusions with which this writer basically agrees:

1. "At present, tongue thrust has no single title or definition." (p. 116)

2. The definition of tongue thrust should include one or more of three conditions: swallowing, speech, and rest position. (p. 116)
3. The association between open bite and tongue thrust does not automatically reveal cause and effect. (p. 117)
4. Thumb sucking is not the major cause of tongue thrusting. (p. 118)
5. "Genetic determinations of jaw relationship are known to be a significant cause." (p. 118)
6. The relationship of tongue thrusting to incisor protrusion cannot be determined from present data. (p. 118)
7. Typically, lingual pressures against the anterior teeth are greater than labial or buccal pressures, even in people with normal occlusion. (p. 121)
8. Habitual anteriorization of tongue position may be a "classic habit" in children who suck their thumb and create an open bite. (p. 122).
9. Children who have an inadequate oral airway find it necessary to carry the tongue low and forward and the mandible lower than usual. (p. 123)
10. The key to solving the above problem is in correcting the respiratory problem (mouth-breathing). (p. 124)
11. Tongue resting position does adapt to changed respiratory conditions. (p. 124)
12. "Many tongue thrusters evolve into a normal adult swallow pattern between eight and 12 years without therapy." (p. 125)
13. Developmental changes during puberty facilitate a more posterior resting position in the oral cavity. (p. 125)
14. Modification of habitual tongue resting posture should be an important goal in therapy. (p. 127)
15. ". . . children are much more variable in their swallowing patterns than the adult population." (p. 128)
16. ". . . there is no reason to recommend any treatment for children who have a tongue-thrust swallow without evidence of accompanying problems." (p. 128)

Areas of Disagreement

Opinions, inferences, and conclusions with which I disagree, either in part, or totally, are the following:

1. ". . . a clinically evident tongue thrust does not necessarily coincide with an open bite malocclusion, and in fact most does not." (p. 117)

This statement is true only when viewed from one perspective. For example, only a relatively small number of children with tongue thrust receiving treatment by speech pathologists or oral myologists have an open bite. An analysis of 200 patients on whom I had kept sufficiently complete records to allow me to study changes in malocclusions during treatment found only 8.6% had open bite as their primary orthodontic problem. 86.4% had overjet as the primary problem, and the remaining five per cent had miscellaneous other types of occlusion.

Research data have generally supported the belief that tongue thrust is present in nearly all patients with open bites. Rogers (1961) compared the incidence of malocclusion and tongue thrust in a general school population of 290 school children and 497 orthodontic patients (ages not given). Of 56 children (ages 5-12) from the school population with open bites, 55 (98.2%) exhibited tongue thrusting. Among his own patients, 78 of 84 (92.8%) were tongue thrusters.

In 1962, Werlich reported on 640 Seattle school children. Only 30.4% of the total group were found to have a tongue thrust. Of the students with open bite, 98% exhibited variant swallows. According to these studies, tongue thrust nearly always accompanies open bite malocclusions.

2. ". . . most open bites are self-correcting when thumb sucking and tongue thrusting disappear." (p. 117)

Proffit and Mason refer to a study by Worms, Meskin, and Isaacson (1971) which reports varying incidences of open bite in five age groups of Navajo children. One conclusion of Worms et. al. was:

> It would be extremely valuable if speech therapy techniques and interceptive cribs designed for open-bite problems would be evaluated on a percentage-of-correction basis. For instance, if a technique corrected open-bite in a certain percentage of the open-bite cases, this percentage of correction should be greater than that which occurs without treatment. In the case of simple open-bite in 7- to 9-year-old Navajo boys, therapy would have to produce completely successful results in better than 80 per cent of the children with open-bite in order to do better than nature and maturity would without therapy. One must be very careful tin taking credit for correction of an open-bite. (p. 594)

No mention of any assessment of manner of swallowing was mentioned in the Worms et al. report. The 1408 children studied were examined for presence of four types, or degrees, of open bite: 1) "simple" open bite, which was defined as the absence of contact between the maxillary and mandibular incisors from canine to canine, not including the premolar, and 1 mm. or greater in centric relation; 2) "compound" open bite, existing from premolar to premolar; 3) "pseudo" open bite, wherein there was vertical overlap of the maxillary and mandibular incisors when the open-bite was less than 1 mm.; and 4) "infantile" open bite, in which the molars were included. Totals of each type were presented in bar-graph form, with a bar for each sex at each of the five age levels. Age levels presented were 7-9; 10-12; 13-15; 16-18; and 19-21. The data below represent my own calculations from the authors' data, which presented boys and girls separately.

Table 1. From Worms, Meskin, and Isaacson (1971). Percentage of 1408 Navajo children at five age groups manifesting compound, simple, and pseudo open-bite. Per cents represent boys and girls combined.

Age	*Compound*	*Simple*	*Total*	*Pseudo*	*Total*
7-9	0.7%	12.8%	13.5%	22.9%	36.4%
10-12	1.8%	2.5%	3.3%	18.1%	21.4%
13-15	2.2%	5.1%	7.3%	14.5%	21.8%
16-18	0.6%	4.6%	5.2%	18.3%	23.5%
19-21	4.7%	1.9%	6.6%	11.2%	17.8%

As the authors indicate, the prevalence of simple open bite was reduced by a factor of five in 10-12 year old children compared with 7-9 year old children. It is important to note that the 12.8% simple open bite among 7-9 year-old children represents 19 of the 148 children studied at this age level, and the 2.5% value at the 10-12 year level represents six children. The number of children at each age level varied from 148 at the youngest level to 503 in the 16-18 year-old group.

The conclusion of Worms et. al. leads one to believe that they assume that all or nearly all those children with open bites would have been seen for tongue thrust therapy. Un-

doubtedly, the open bites of many children were minimal. Few patients are referred for myofunctional therapy when they exhibit small open bites extending from canine to canine. Certainly, the majority of those who have open bite and are referred for therapy have either relatively severe "simple" open bite, or have the "pseudo" or "compound" types of open bite, or have the "pseudo" or "compound" types of open bite. For this reason, I have included these two category totals colums.

Notice, though, before referring to these columns, that the incidence of open bite increased (doubled) at the 13-15 year level over the incidence in the 10-12 year-old group. If, as the authors indicate, there was an 80% drop in incidence from the first to the second age group, they would also have to conclude that 25% of those who self-corrected would revert to an open bite during the next three-year period.

Notice the increase in incidence as age increased in the "compound" column. Because so few of the children had this severe an open bite, the percentages have relatively little effect on those listed in the first of the two "totals" columns. Significantly, though, at the 13-15-year level, there are more than 50% as many with a "true" open bite as at the 7-9-year level. So, to cite only the one statistic concerning the simple open bites is a little misleading.

Into the "pseudo" group were placed children with very minimal open bites accompanied by overjets. The caseload of a clinician working with tongue thrust includes several times as many of these children (as the reported percentages in the Worms et. al., study would indicate) than children with simple open bites. When those children are included, the incidence-by-age picture changes drastically. Even in the 19-21-year-old group, there are nearly half as many as in the 7-9-year group, and the incidence even increases slightly between the ages of 10 and 18. The incidence diminishes by only 41%, instead of by 80%, between the ages of 7-9 and 10-12. Viewed in another way, if all those who had any kind of open-bite malocclusion at 7-9 years *did* have a tongue thrust, and all were seen for therapy, rather than having it postponed until the age of 19, 35.4% would have received therapy needlessly.

In all likelihood, most of the children with mild "simple" open bites would not have been referred by the orthodontist to the myologist at such a young age. In my experience most orthodontists recognize that many very mild, simple open-bites self-correct soon after the principal stages of mixed dentition have been completed.

The principal criticism of the Worms et. al., study is that it makes inferences about a decline in incidence of open bite as age increases from non-longitudinal data. If the number of subjects with open bite in each year of their research were large among the youngest subjects and progressively decreased with each successive age group, such inferences might be defensible. Such is not the case. Only in a longitudinal study, wherein the same children are seen from year to year, can valid statements be made concerning changes in malocclusion.

Of the 178 eight-year-olds seen in 1970 in the Hanson-Cohen (1973) research, 18 had an open bite, including those children with open bite as the only malocclusion, and those with open bite and other occlusal problems as well. In 1974, (Hanson and Hanson) of the 18, 12 were located and agreed to participate in follow-up research. One of these had received orthodontic treatment (retainer only), and none had received therapy for tongue thrust.

At eight years of age, the mean open bite among the 12 children was 2.5 mm., and the range was from 0.5 mm. to 5.0 mm. Eight of those subjects had overjets in addition to an open bite, with a mean of 4.2 mm., and a range of 1.0 mm. to 7.5 mm. Five were tongue thrusting and seven swallowing normally.

When these same children were seen four years later, only four retained an open bite. (Open bite was defined as a vertical space between at least two pairs of maxillary and mandibular teeth, with a mean of at least ½ mm. between the two pairs with greatest separation). The mean was 1.4 mm. and the range 0.5 mm. to 4.0 mm. However, eight now had overjets, with a mean of 3.8 mm., and a range of from 1.5 mm. to 4.5 mm. Of the eight with overjets, only one now retained an open bite. Eight were now tongue thrusting and four were swallowing normally.

Hence, even in a longitudinal study, if only the open bite data were considered, a very incomplete assessment of the effects of maturation upon occlusion could be reached. The Worms et. al. inference that most of the swallowing therapy that might have been prescribed for the younger subjects in their study would have been administered needlessly seems unwarranted.

Reference is again made to the present writer's 19 private patients with open bite. The mean open bite among these patients was 3.58 mm. at the beginning of therapy for tongue thrust. The open bites of only four of those 19 patients were reduced to less than 1 mm. without orthodontic treatment. The other 15 were later treated orthodontically. It is very doubtful that spontaneous remission of open bite in cases serious enough to be referred for therapy for tongue thrust occurs to any significant degree without treatment of any kind.

3. In a separate lingual pressure study, it was found that for speakers with frontal lisps, the "th" sound appears to be an "s" substitution physiologically as well as acoustically. That is, the pressure patterns used by frontal lispers on "th" for "s" substitutions were closer to the lingual pressure used on "s" than "th." Thus, lingual pressures used by many tongue thrusters do not represent unnatural or excessive forces applied to the maxillary alveolus or anterior teeth, but rather an apparently simple substitution of one sound for another. (p. 120)

I interpret the concluding sentence to be a product of faulty reasoning. Since "A" (lingual pressures used by normal speakers on the production of "s") is more natural than "B" (lingual pressures used by normal speakers on the production of "th"), and "C" (pressure patterns used by frontal lispers on "th" for "s" substitutions) is more similar to "A" than "B", "C" is therefore not unnatural (or excessive). The conclusion represents a dichotomization (i.e., natural vs. unnatural), whereas the reasoning leading to the conclusion involves *degrees* of similarity.

The authors then conclude that to catalogue speech behavior as tongue thrusting simply because a frontal lisp is present is questionable. Most clinicians would agree with this conclusion. Many frontal lispers are not tongue thrusters. On the other hand, when a lisp is evident, it is wise to watch and listen to the other linguo-alveolar consonants, to determine whether dentalization of these sounds is occurring. There may well be a pattern of tongue-fronting all the tongue-tip sounds. Such a pattern should signal the speech clinician to investigate the possibility of the presence of tongue thrust swallowing and forward lingual resting ¡ ostures in a given child.

4. "Tongue thrust, as usually defined, does not typically lead to dental malocclusion in the form of anterior open bite or protruding maxillary incisors." (p. 120)

There are, to my knowledge, no well-controlled studies that prove the existence *or* non-existence of a cause-and-effect relationship between tongue thrust and malocclusions. Such relationships have been assumed by many when both phenomena were found to co-exist to a statistically-significant degree, and have been presumed to not exist by

those who have found that lingual pressures exceeded labial pressures in people with normal occlusion. Neither phenomenon establishes the presence or absence of cause-and-effect patterns.

5. "It has been observed that there is no balance of pressures against the teeth. The expansive forces of the tongue are never balanced by the containing forces of the lips, even when prolonged periods of time are considered."

Several studies are referred to at this point (Gould and Picton, 1964; Lear and Moorrees, 1969; and Proffit, Chastain, and Norton, 1969). The word "balanced" is important, as is the word, "never."

Regarding the balance between labial or buccal and lingual forces exerted against the teeth: People who give therapy for tongue thrust are primarily concerned with the anterior dentition, and sometimes with the bicuspids. Most of the patients present overjets, involving usually the maxillary incisors and canines. It is true that lingual pressures as measured by several researchers nearly always exceed labial and buccal pressures. If "balance" means "equal," then the forces may not balance. If "balance" is considered a transitive verb, and the direct object is the teeth, it acquires a different meaning. A 200-pound man and a 100-pound boy can balance a seesaw, if they sit in the right places. In the same way, dentition, especially the anterior maxillary dentition, may be balanced by unequal intra-oral and extra-oral forces.

Brader (1972), discussing the geometry of the dental arches and the effects of opposing muscular forces upon those arches, theorized:

". . . it is now possible to postulate that the teeth do reside in positions of equilibrium forced anteriorly and laterally by the internal field of forces of the tongue masculature . . . and counterbalanced precisely along the interface between the teeth and the labio-buccal mucosa by the inward tension of the enveloping tissues . . ." (p. 553)

The reason teeth normally remain "straight" may be found in the architecture of the teeth and their supporting structures. Strang and Thompson (1958) explain:

The bone (of the alveolar process) is arranged so as to give the greatest possible support with the least possible bulk and where there is an increase in bulk it is to meet some special force. (p. 267)

They continue:

Consequently, on the labial surface of the incisor roots we find a compact area of bone just at the gingival margin but a comparatively thin deposition of osseous tissue overlying the remainder of the roots. On the lingual side, however, the bone is thick and bulky, especially in the maxillary denture where the incisors are inclined labially to a greater degree. (p. 269)

And further:

Bone is most dense but least in amount on the side against which the forces have been exerted in development and less dense but greater in bulk on the other sides from which the forces have come. Applying this to the alveolar process, we would expect to find denser bone, but of smaller bulk, on the labial and buccal sides of the roots and less dense but more bulk of bone on the lingual aspect, and this certainly is the case. (p. 269)

A characteristic of many tongue thrusters with overjet is that the maxillary incisors are tipped labially. When the apex of the tooth is moved labially, the root is moved lingually. The greater bulk in the bone on the lingual aspect, at the root of the tooth, helps keep the incisor "in balance" when, as in normal occlusion, the lingual pressures are greater than the labial pressures. This may be seen in illustrations from Sicher and DuBrul (1970).

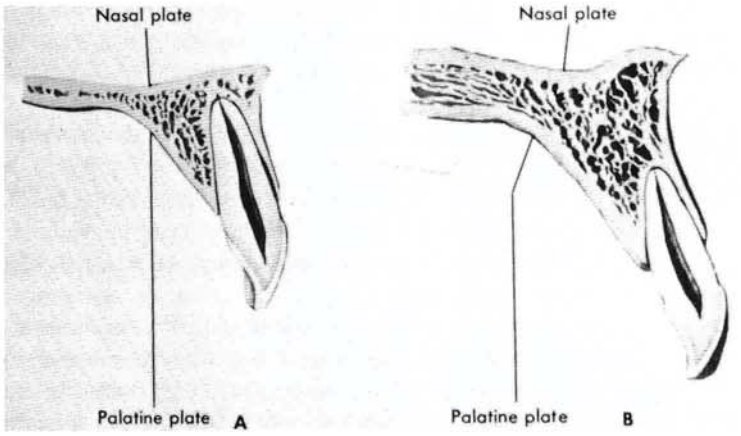


FIG. 1 Labiolingual sections through the upper first incisor. (Sicher and Tandler: Anatomie für Sahnärate, p. 387)

This difference between amounts of "bulk" of bone tissue is not seen in sections of the corresponding mandibular teeth.

If, then it is normal for lingual pressures to exceed labial pressures in people with normal occlusion, the question arises, "Do even greater differences between lingual and labial pressures occur in people with tongue thrust and/or malocclusions?"

Mendel (1962) compared labial and lingual pressures of five teen-aged females whose corrected occlusions had remained stable for at least one year after the retention phase of treatment with those of six females of similar ages who had relapsed into an anterior open bite and who exhibited a tongue thrust. The findings were:

The mean tongue pressure for all of the open bite cases was 285 gm/cm² as opposed to 128 gm/cm² for the control samples. The mean upper lip pressure of the open bite sample was 45 gm/cm² while the closed bite sample had a mean pressure of 70 gm/cm². The ratio of tongue to lip pressure in the relapse group was 6.3 to 1.0, and in the group with stable dentition, 1.7 to 1.0. This finding would seem to support the hypothesis that tongue pressures may contribute to malocclusion.

One of the studies cited by Mason and Proffit was Proffit, Chastain, and Norton's (1969). Twenty-two children, six of whom had been found clinically to have a tongue thrust, were examined to determine lingual pressures during speech and swallowing. Transducers were placed lingual to the maxillary central incisors and near the second molars. Data from 100 swallows collected in repeated recording sessions of six children showed stronger lateral than anterior pressures. The average peak pressure for the center transducer was 85.9 gm/cm². The authors report that their data are typical of the child population.

They state that, whereas two of the six tongue thrusters had the heaviest anterior pressures of any children in the group, the other four showed little or no lingual pressure against the anterior transducer. Indeed, these four demonstrated the least anterior pressure of the total group. This finding makes the efficacy of their clinical determination of tongue thrust questionable. Although it is theoretically possible that the tongue be placed between or against the incisors with little or no pressure being exerted against the teeth during swallow, the effects of the pressure in nearly all children I would diagnose as

tongue thrusters are clearly visible as the anterior tongue forms a tight seal against the anterior dentition. Possibly, in spite of these researchers' efforts to construct a tiny transducer, its presence still constituted an artifact that produced a change in tongue behavior in these children.

The second study Proffit and Mason cite to support their contention that there is no balance of pressures against the teeth is that of Gould and Picton (1964). This research studied buccal pressures *only*, not buccal or labial versus lingual pressures. The only imbalance reported by Gould and Picton is a bilateral asymmetry of pressures in their subjects, which has little significance in the absence of any data to indicate whether lingual pressures were correspondingly asymmetrical.

The third study cited by Mason and Proffit is that of Lear and Moorrees (1969). In spite of the small number of subjects in this research, it is important because of its attention to all types of lingual and buccal pressures during customary daily oral activity. Seven adult males with normal occlusion were studied with strain gauges placed lingual and buccal to the premolars. Measures were taken during speech, mastication, deglutition, and with the oral musculature in a state of rest. The amount of time apportioned daily to each type of oral function was recorded with automatic equipment in the subjects' own homes.

Although general conclusions from the analysis of the data are given pertaining to the total group, specific data regarding the "gram-minutes of force" are included in the Lear-Moorrees article for only one subject, number four. The *general* conclusions include:

1. With some exception during speech in one subject, the right-side musculature always produced totals similar to those of the left.
2. Only one of the seven subjects (number two) showed a close counter-balance between buccal and lingual forces in *both* (both is italicised by the authors) arches, if a ratio of 0.9 to 1.2 is accepted as reasonably close to equality. Otherwise, lingual forces always exceeded those from the cheek by factors varying from 1/2 to almost 4. For the group as a whole, lingual forces differed significantly from buccal forces ($p < 0.01$), but between-subject variations were such that the extent of the maxillary-mandibular differences could not be defined.

Subject number four, then, was not one, according to the authors, in whom lingual and buccal forces were in balance. This is true when mandibular and maxillary totals are combined, but not when only the maxillary pressures are considered. Again, since the great majority of tongue thrusters seen for therapy have maxillary overjets, it is important to examine the maxillary data separately. For subject four, there was a close "counter-balance" between lingual and buccal forces in the maxillary arch. The total lingual to buccal pressure ratio was 0.9. Total pressures, expressed in gram minutes, against the transducer placed lingual to the left maxillary premolar, were 1628. Buccal pressures near the same tooth totalled 1705 gram-minutes. Similarly, lingual totals for the right maxillary premolar were 1537 gram-minutes, compared to 1660 for the buccal totals. On both sides of the mouth, at the level of the maxillary premolars, total buccal pressures were greater than total lingual pressures.

Data for this one normal adult subject indicate that it may be possible, when maxillary pressures are considered separately, and when resting pressures are included in the computations, that labial and lingual pressures have relatively equal values.

Weinstein (1967) reviewed a series of investigations into the effects of light, constant pressures on tooth position, and concluded that muscle forces of as little as 1.68 grams above the resting force, persisting over a period of time, are capable of moving teeth. He

reports an experiment in which a child's premolar moved nearly one mm. in eight weeks, due to a gold onlay being secured to the buccal surface of that tooth. The onlay increased the buccal pressure on the premolar by only 1.68 grams.

Proffit and Mason agree that lingual resting pressures may be an important factor in malocclusion. If the tongue rests continuously against the anterior maxillary teeth, the light, constant pressures might affect the incisors, which move much more easily than do premolars, in a manner similar to the movement of the premolar in the research described by Weinstein.

Lear and Moorrees (1969) projected 24-hour totals in terms of gram-minutes of pressure. From their data on the left central maxillary incisor of subject four, the following totals were computed:

Total lingual pressure: 851 gram-minutes. Mean pressure: 0.59 grams.

Total buccal pressure: 1182 gram-minutes. Mean pressure: 0.92 grams.

Mean ratio, lingual to buccal pressure during rest: 0.64 to 1.00.

If for any reason the equilibrium discussed by Brader (1972) were upset in such a way that this ratio was increased, it seems logical, in view of Weinstein's findings, that the anterior teeth might, over a long period of time, be tipped labially. Furthermore, once the tipping process began, whatever its cause, the constancy of the labial or buccal pressure would be likely to diminish, due to the increasing difficulty of keeping the lips closed at rest over the protruding incisors.

Studies similar to that of Lear and Moorrees need to be made in which pressures during the various oral activities are measured over a prolonged period of time in children with tongue thrust and malocclusion, and compared with those of children with normal occlusion. Maxillary and mandibular pressure patterns should be included and studied separately as well as in combination.

BIBLIOGRAPHY

Brader, A.A., Dental arch form related with intraoral forces: PR = C. *American J. of Orthodontics,* **61:** 541-561, 1972.

Gould, M.S.E., and Picton, D.C.A., A study of pressures exerted by the lips and cheeks of subjects with normal occlusion. *Arch. Oral Biol.,* **9:** 469-478, 1964.

Hanson, M.L., and Cohen, M.S., Effects of form and function on swallowing and the developing dentition. *American J. of Orthodontics,* **62:** 63-82, 1973.

Hanson, T.E., and Hanson, M.L., A follow-up study of longitudinal research on malocclusion and tongue thrust. *The Intern. J. of Oral Myology,* **1:** 21-28, 1975.

Lear, C.S.C., and Moorrees, C.F.A., Buccolingual muscle force and dental arch form. *American J. of Orthodontics,* **56:** 379-399, 1969.

Mason, R.M., and Proffit, W.R., The tongue thrust controversy: background and recommendations. *J. of Speech and Hearing Disorders,* **39:** 115-132, 1974.

Mendel, R.A., Tongue and lip forces exerted on the maxillary central incisor during swallowing. Unpublished master's thesis, University of Washington, 1962.

Proffit, W.R., Chastain, B.B., and Norton, L.A., Linguopalatal pressures in children. *American J. Of Orthodontics,* **55:** 154-166, 1969.

Rogers, J.H., Swallowing patterns of a normal population sample compared to those of patients from an orthodontic practice. *American J. of Orthodontics,* **47:** 674-689, 1961.

Sicher, H., and DuBrul, E., *Oral Anatomy.* St. Louis: The C. V. Mosby Company, 1970.

Strang, R., and Thompson, W.M., *A Textbook of Orthodontia.* Philadelphia: Lea and Febiger, 1958.

Weinstein, S., Minimal forces in tooth movement. *American J. of Orthodontics,* **53:** 881-903, 1967.

Werlich, E.P., The prevalence of variant swallowing patterns in a group of Seattle school children. Unpublished master's thesis, University of Washington, 1962.

Worms, F.W., Meskin, L.H., and Isaacson, R.J., Open bite. *American J. of Orthodontics,* **59:** 589-595, 1971.